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(64) Electromagnetic machines

(57) An electromagnetic machine which may be, for example, a motor or a generator comprises a housing member (3,4) defining at least one tubular space (7) between inner and outer cylindrical surfaces. A plurality of electrically conductive rolling elements (1) are disposed in the space (7) and are supported by an equal plurality of rollers (2). Means for producing a constant or variable radially directed magnetic field across the space (7) is also provided.

Figure 7

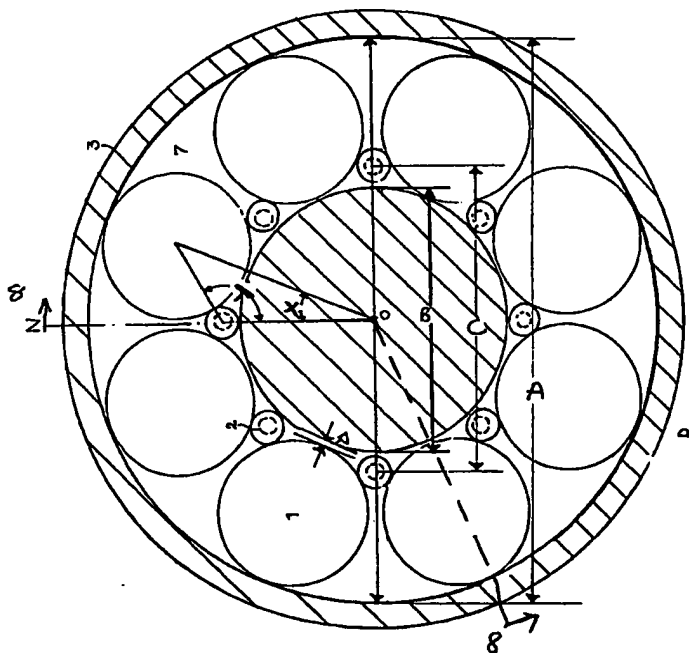


Fig 1

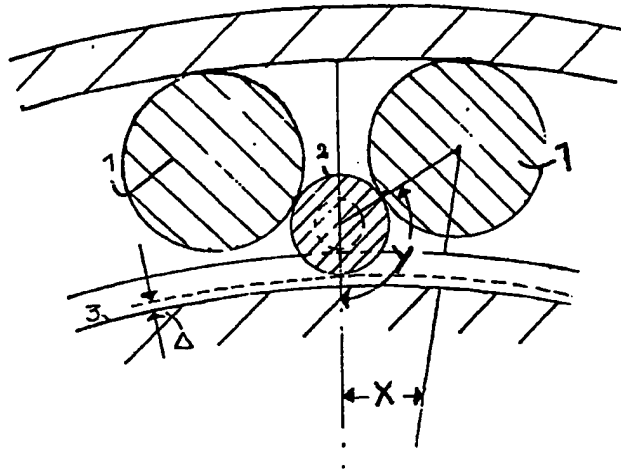


Fig 1A

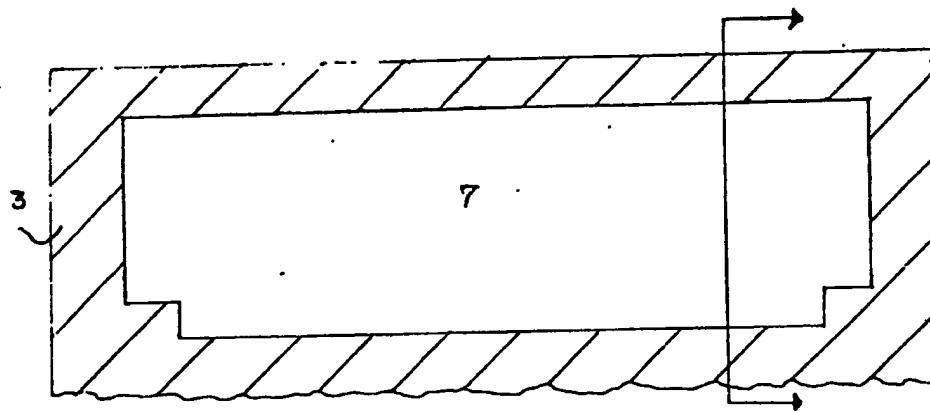


Figure 1B

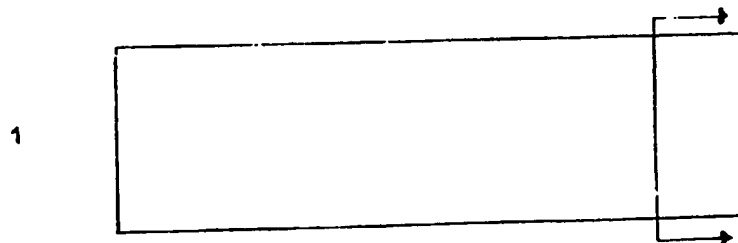


Figure 1c

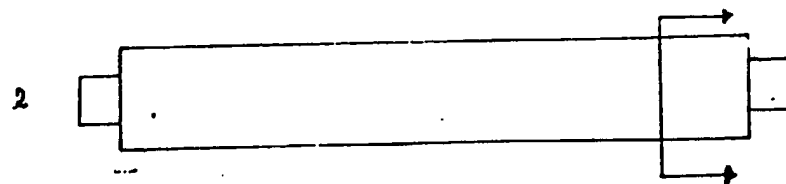


Figure 2.

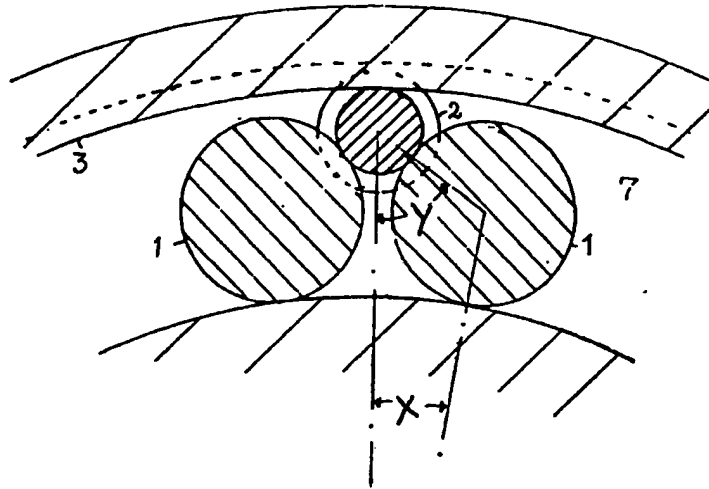


Figure 2A

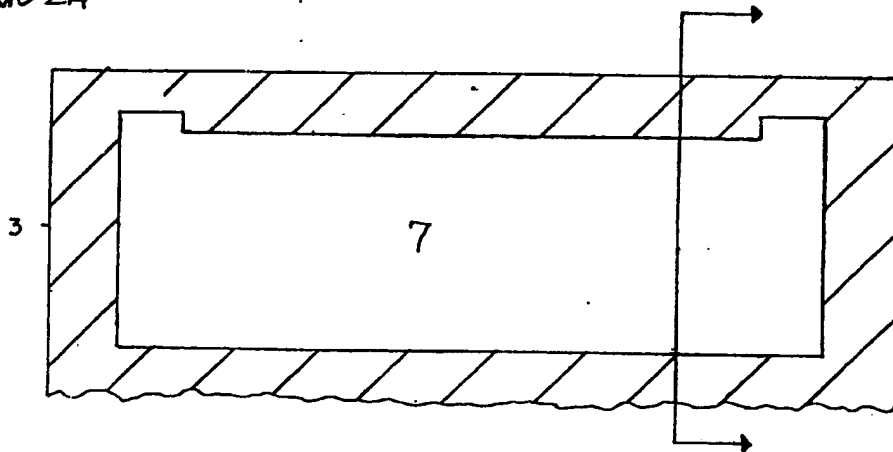


Figure 2B

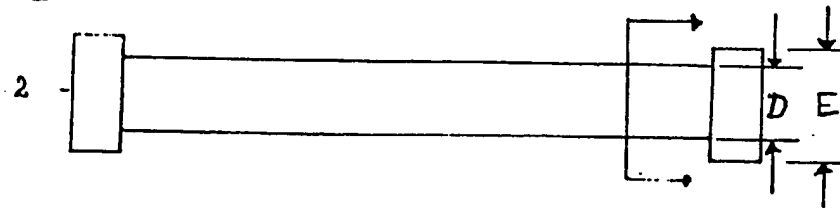


Figure 2C

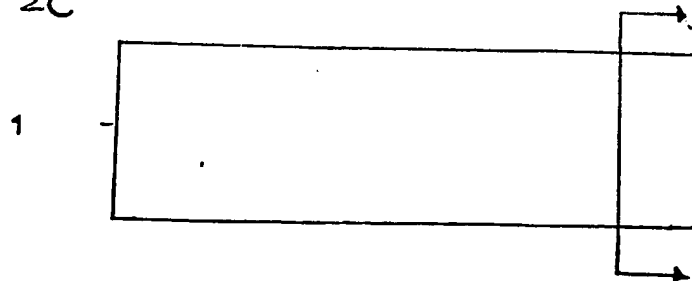


Figure 3

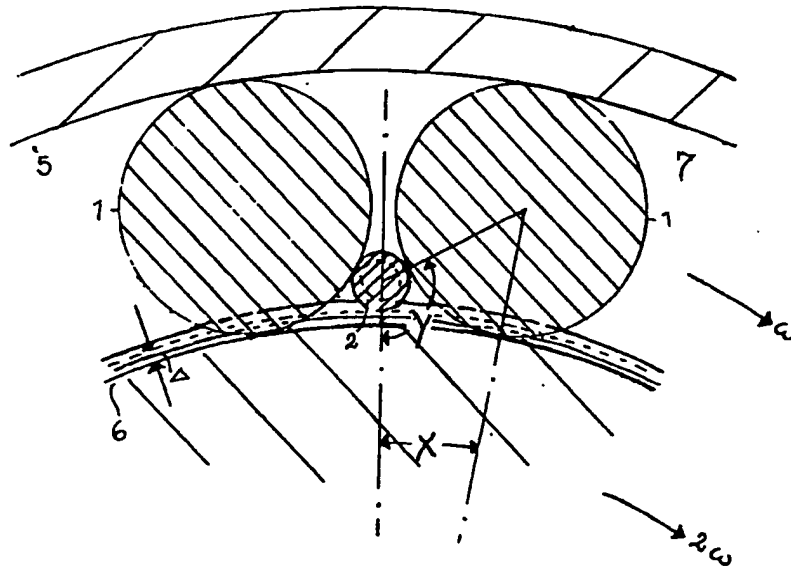


Figure 3A

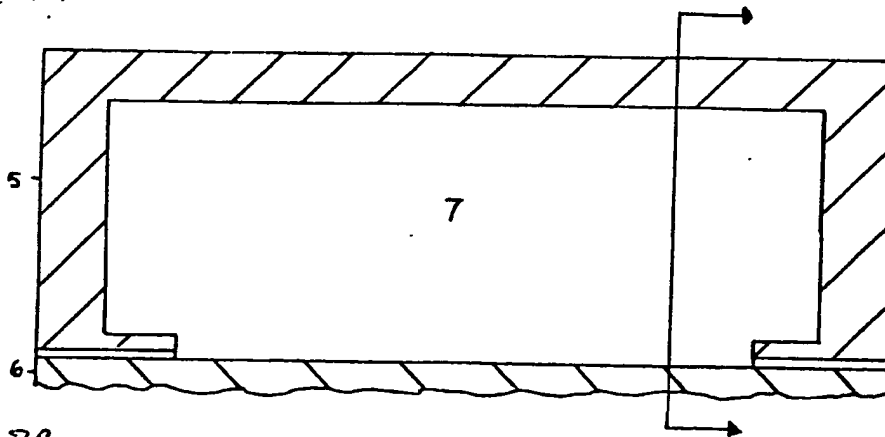


Figure 3B

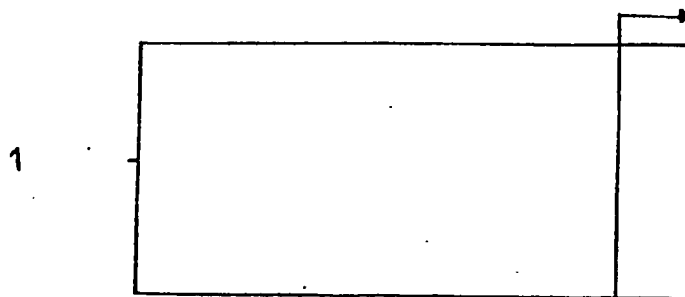


Figure 3C

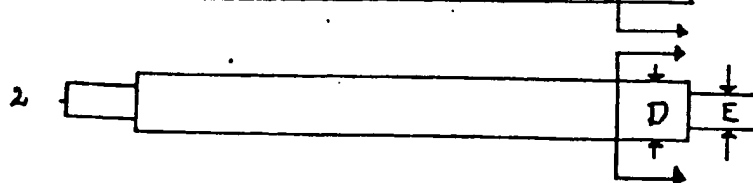


Figure 4

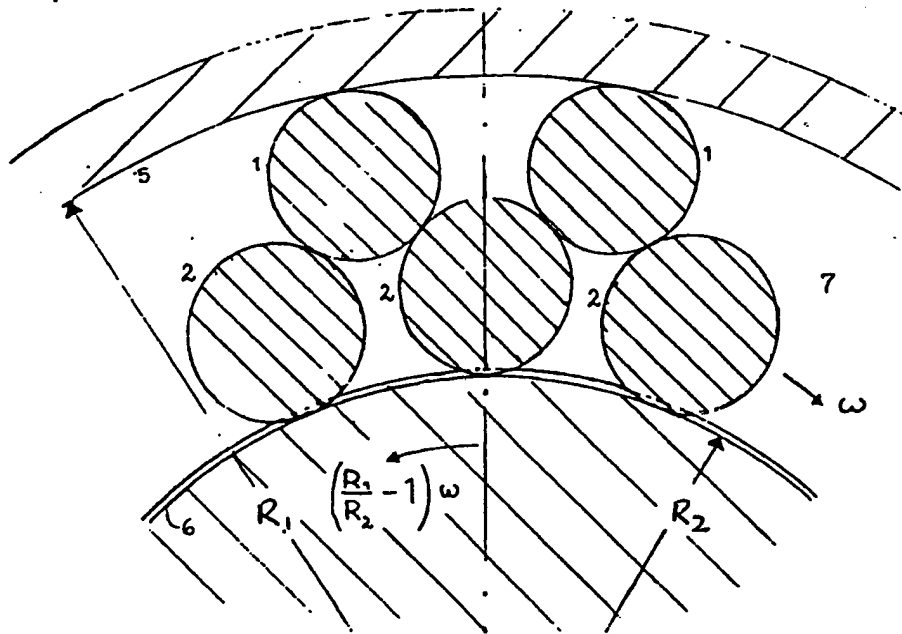


Figure 4A

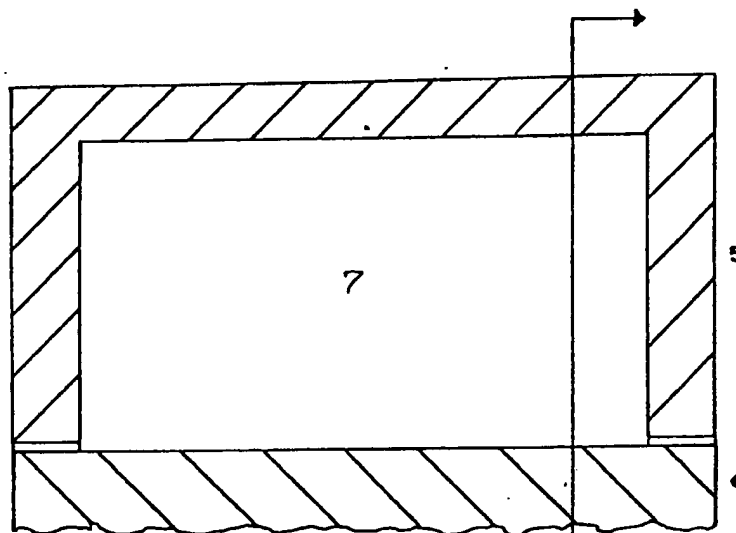


Figure 4B

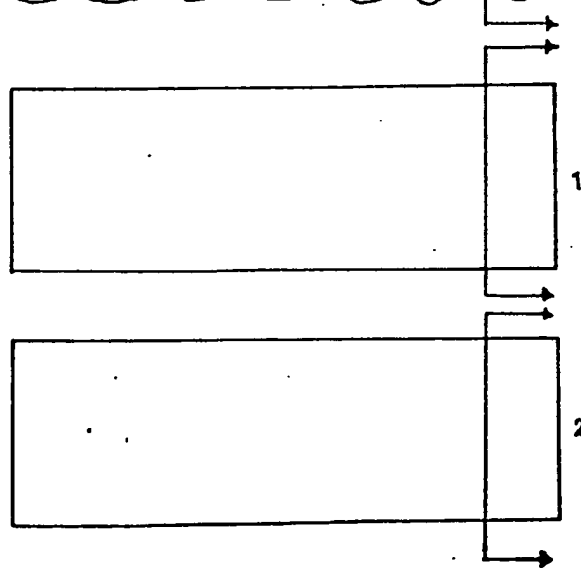


Figure 4C

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Figure 5

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Figure 9

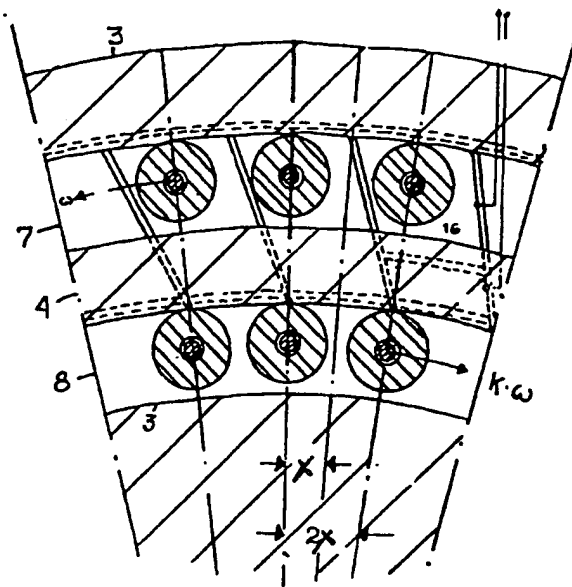


Figure 10

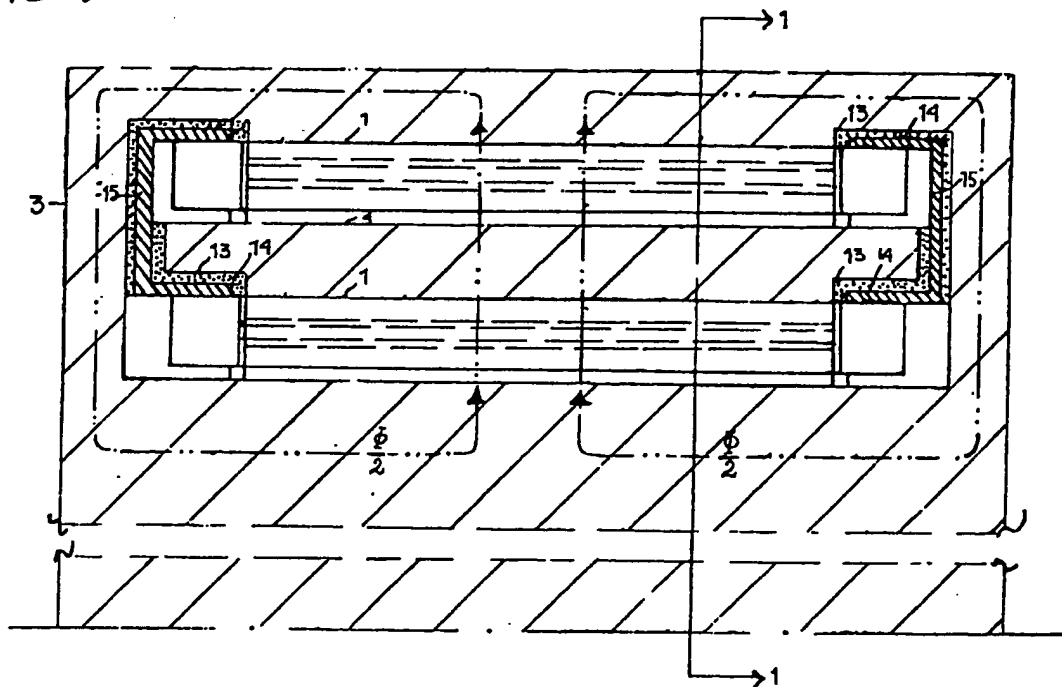


Figure 11

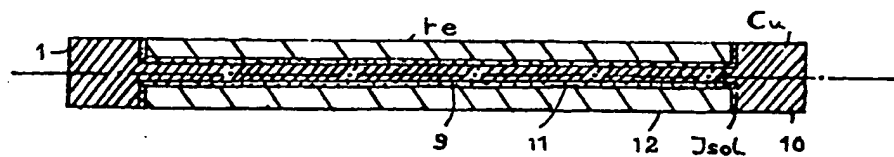


Figure 12

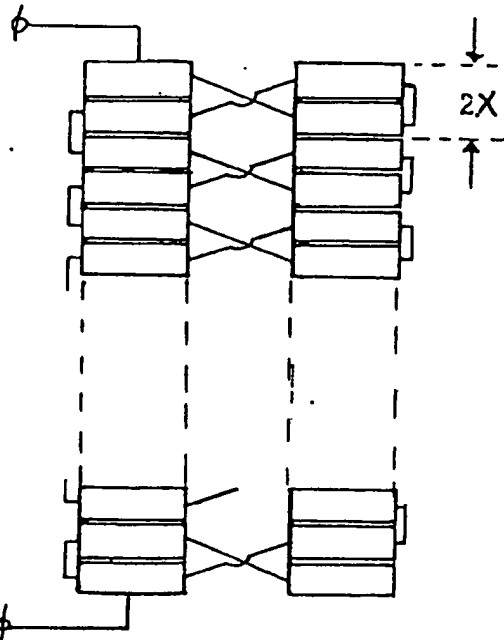


Figure 13

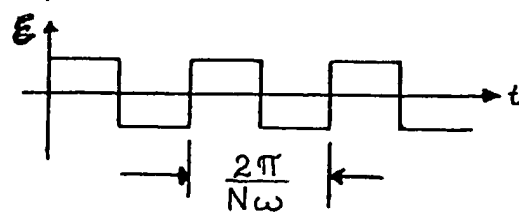
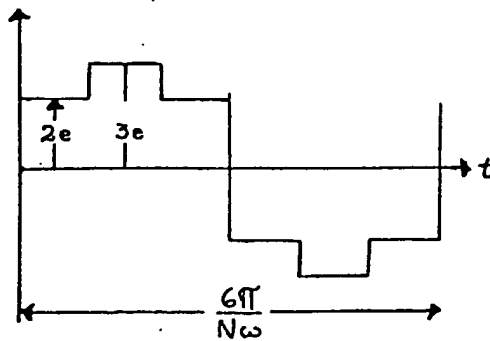


Figure 14



SPECIFICATION

Improvements in or relating to electromagnetic machines

5 The present invention relates to improvements in or relating to electromagnetic machines.

The machines of the present invention may utilise a physical construction as disclosed in United Kingdom Patent Application No. 41790/78 published as
10 GB 2008204A relating to bearings the disclosure of which is incorporated herein by reference.

The present invention includes an electro-magnetic machine comprising a tubular space defined between inner and outer races, means for
15 producing a radially directed magnetic field in the space, and an equal plurality of alternately arranged rolling elements and rollers disposed for free movement within the space, at least the rolling elements being electrically conductive.

In order that the invention may be well understood several embodiments thereof will now be described, by way of example only, with reference to the accompanying drawings in which:

25 *Figures 1 to 6* show partial transverse cross-sections through respective electromagnetic machines;

Figures 1A, 2A, 3A and 4A show respective longitudinal sections through housing members of
30 the various relative machines;

Figures 1B, 2B, 3B and 4B show respective longitudinal sections of rolling elements used in the various relative machines;

Figures 1C, 2C, 3C and 4C show respective longitudinal sections of rollers used in the various relative
35 machines;

Figure 7 shows a transverse cross-section through another electromagnetic machine;

Figure 8 shows a section on the line 8-8 of *Figure 7*;
40

Figure 9 is a partial transverse cross section of yet another type of electromagnetic machine having two coaxial tubular spaces with rollers omitted for clarity;

45 *Figure 10* is a partial longitudinal cross-section through the machine of *Figure 9*;

Figure 11 is a section through a conducting rolling element of the machine of *Figures 9 and 10*;

Figure 12 shows a method of connecting the conducting rolling elements of the machine of
50 *Figures 9 to 11*; and

Figures 13 and 14 show different waveforms which may be produced from the electromagnetic machines described when used as generators with
55 the conducting rolling elements suitably interconnected.

The actual invention shows new constructions of electrical motors, accumulators etc., achieved by arrangement in groups of usually serial-connected
60 electrical conductors, which rolling freely rotate in a radial magnetical flux. From the invention it is clear that electrical currents and voltages can be transformed and that electrical power/energy can be transferred to rotating mechanical power/energy as
65 well as transformed in the opposite direction. The

invention also includes quite new types of mechanically active energy-units.

The known electrical apparatuses used induction-effect $E_i = d\phi/dt$ and the force-combine $F = I \cdot B \cdot L$
70 is normally not directly coupled to rotational energies of the form $I \cdot \omega^2/2$. For transforming voltages and currents without the mechanical way via rotating converters only alternating fields have been used for the $d\phi/dt$ -effect. Further it is valid for rotating
75 electrical apparatuses that the active electrical conductors are rigid connected with rotating masses. The needed magnetic flux passes an apparatus section, space- or unit-fixed.

One of the main principles in the actual invention
80 is based upon, that only the current-carrying conductors circularly rotate in a radially directed magnetic flux and and that the magnetic-field producing unit as normally has not to be fixed in space.

A first main principle points out methods to carry
85 out this rotation of the current conductors within the magnetic unit with a sliding- and frictionfree- rolling off of the conductors between the surrounding cylindrical surfaces, also compare the U.K. patent application No 41790/78 regarding roll-bearings. An even number $(2 \cdot N)$ specific formed rolls respectively
90 supporting rolls and to them an adapted cylindrical cavity, 7, in *Figures 1-11*, is on that point a condition.

The invention indicates two main groups of this mechanical functioning of the rolls. In the first case
95 the rolls, 1, in *Figure 1, 2, 9, 10, 11* at continuous and constant rotational velocity, are completely free from tangential influence from or on the surrounding system, 3, in *Figures 1, 2, 5 and 6*, and the parts, 3 and 4 in *Figure 9, 10, 11*, of the system. In the second
100 case the rolls cooperate mechanically by friction contact with the surrounding system as shown in *Figures 3 and 4*. This surrounding system is then formed by two mutually free rotating and concentric system-halves, 5 and 6 in *Figure 3 and 4*.

With reference to *Figure 1, 2, 3, 5 and 6* respectively and patent claims 2, 4 and 5 it is clear how every
105 second supporting roll, 2, and its centre of axis with $Y < 90$ degrees, see *Figure 2*, radially is placed outside or with $Y > 90$ degrees, see *Figure 1, 3, 5 and 6*, is placed inside the plane through the centers of the axis of the nearby rolls. An univocal ratio of radius of the supporting rolls for slidingfree rolling and rotation is achieved from formulae in the
110 aforementioned UK Patent Application No 41790/78.

The measures and angles given in the *Figures* and the formulae define the actual ratio of the radius. There is also a possibility with completely cylindrical supporting rollers or rolls, 2, to give the rolling elements or main rolls, 1, an univocal ratio of radius.
120 For such variants somewhat changed but not nearer specified formulae are valid. The same is also possible for a combination of different ratio of radius for both rolls and supporting rolls. The even number of all rolls, the absolute values of the radius of rolls and cavity as well as the axial dimensions are optional free within wide limits. An upper respectively lower limit, Δ , in *Figures* is given from patent claim 5 for one of the radius of the cavity.

In *Figures 9 to 11* one excitation with double,
130 concentric cavities mainly adapted for accumulating

energy has been shown, then simplified and drawn with only one half of all rolls, 1, in the cavity and then for the case $\gamma > 90$ degrees. Other executions with a number of concentric systems of rolls makes a good exploitation of the volume and by that way a high energy-density. How the fluxes in the different cavities are produced and the possibilities to steer, distribute and vary these with known methods has been passed over, because the main principles of the invention are not affected of that.

Lowest in Figure 11 is shown one of many executions of the rolls, 1, with electrically conducting central- and end-parts, 9 and 10, with electrically conducting central- and the main part of the roll, 12, which suitably is made from a magnetically well conducting material. On both sides of the frame N number of collector sections are attached, 14, towards the frame and mutually isolated, 13, which form rolling-off surfaces as well as current connections for the roll-conductors. In the general execution with one cavity from Figures 1 to 6 from outside accessible and isolated connections to each collector section on both sides shall be arranged for serial and/or parallel connection of one or more groups of sections. In the model in Figure 9-11 for simple and internal serial connection of all roll-conductors the nearby segments, 14, for the two cavities have mutually been displaced by X degrees with intercoupling, 15, however, except one intercoupling, 16, which is used for outside current connectors. The X-angle is defined as $X = 360/2N$.

In Figure 9-11 and then when connected to an outer DC-voltage, current-limiting at upstarting with by example an inductance, the countermoving circular rotations of the two rollsections are commenced and reach these quickly the rotational velocities ω and ω shown in the Figure with the relation $\varepsilon_i = \frac{1+k}{2} \cdot \omega \cdot N \cdot \phi$. The difference between the voltage from outside ε and the inner induced counter-emf ε_i is driving a current through the roll-conductors and the inner resistance R of the system. At rotational balance the idling current and its driving force and combined angular momentum will compensate actual friction-, hysteresis- and ohmic losses in the roll sections. If these losses are unequal for the two sections then $\omega \neq k \omega$, but an equality can be reached by an adapted flux density by shunting the field in one of the cavities, by a different current-distribution etc. The power consumption from the outer voltage source at a continuous rotation and at a low value of R will practically be independent of this resistance and proportional to the losses from friction and hysteresis. Because the friction losses especially at evacuated systems practically are non-existent and the other by an adapted ferromagnetic material in and an eddycurrent-limiting construction of the main part of the roll-conductors, the idling losses will be neglectable.

When the outer voltage source is disconnected after a starting up of the system the inbuilt rotational energy will remain. The system will act as an electro-mechanical accumulator. The voltage adjustment when connecting an outer load is done by regulating the field strength inverse proportional to

the speed of revolution. With an additional idling losses due to hysteresis can be reduced to zero by a total demagnetizing, $\phi = 0$. This gives an opportunity to a longduration energy conservation, only limited by the losses of the hysteresis type of mechanical deformations due to centrifugal forces respectively to losses from micro-sliding.

For a maximal conservation of energy the rolls of the system shall space-rotate with a maximal allowed surface speed of v m/s with an accepted security margin to the explosion limit of v_{max} . This means, because the surface speeds will be proportional to the outer radius of the actual cavities, that the rotation speeds of the sections shall be adjusted inverse proportional to these radius with by example adjusted flux densities.

In the general case with equal directed circular rotations the rollstored rotational energy also can be transformed to rotational energy of the system surrounding the cavity or cavities if this system is fixed to a shaft with bearings, i.e. if it is given a motor performance. The transformation is done by shortcircuiting of the connections to the collectors respectively by adjustment of the magnetic flux.

Without an outer mechanical load on the shaft of the system such an energy transfer and a total rotation of the system will be achieved optionally quick so that the relative rotation between system and rolls, the internally induced emf and then also the current through the roll-conductors ceases. However, if the shaft simultaneously is loaded with an outer torque, i.e. that the arrangement is functioning as a driving motor, finally the situation is reached, when all internal and relative rotational energy is transferred to the outer load and the driving force disappears.

Continuous and constant motor action is achieved from above described effects with a time controlled and alternating switching between energy conservation and energy delivering. The inertia of the load will then equalize the pulsations. During the period of energy storing the reaction of the system shall not react on the load but shall be transferred and coupled to the frame, which by example means an addition of a counterrotating free-coupling to the load.

The alternative is a simultaneous intake and outtake of energy. A suitable chosen part of the roll-system, and most simple then at systems with one cavity, will then function as shortcircuited with an electromagnetical locking effect between the outer energy consumption and the internal energy of the roll-system. Other parts of the roll-system are given rotational energy from electrical energy via to these parts belonging, open collector contacts, which then are connected to an outer voltage source. The alternating switching of turning forces to rotor respectively frame can be arranged with two alternatively functioning flux systems, formed in rotor respectively frame. The systems of rolls and fluxes shall then bring simultaneous activities.

The task to transfer electrical energy to other forms of electrical energy, i.e. voltage- and current transformation, is solved by using the step-transformer-like contacts from the collectors of the serial connected roll-conductors. Alternatively from

each other electrically separated part-groups of the total number of active rolls are used. This gives current-ratios following the known transformer expression $I_1 N_1 = I_2 N_2 = \text{etc.}$ and voltage-ratios from

$$V_1/N_1 = V_2/N_2 = \text{etc.}$$

The inverted motor performance, i.e. generating electrical energy from mechanical with its symmetrical characteristics have not to be described. In the same way as has been explained in the above motor section current is forced back to the voltage source $E(I \cdot R_v)$ when the outer connected momentum forces the rotational direction to change sign and $E_i = I(R + R_v)$ or $E_i = I R + E$.

For adaption of ordinary AC-lines to the above described electromagnetical systems and then in the first case for motors, converters and accumulators it is necessary that the magnetic field shall vary synchronously with the outer voltage source, suitably then with parallel feed fieldwindings. For AC-generators as for converters from DC to AC Figure 12 is referred to where midparted and crossconnected collector segments will deliver square-formed AC when magnet-flux is constant. The amplitude of this flux determines the rotation frequency from $\omega = 2\pi \cdot E/N \cdot \phi$ and from that the pulse-frequency $f = E/\phi$. If a more sine-formed outgoing voltage asked for, every collector segment can be divided into an even number of partsegments, by example 6, with a curve form given in Figure 14, alternatively filtrated with known methods or generated by a controlled and sine-formed magnetic field-flux etc.

As a mechanical alternative to the above described forms in Figures 1,2,5,6,9,10 and 11 with a the cavity/cavities surrounding homogenous system it is shown in Figure 3 a parted system for $Y > 90$ degrees comparable to an ordinary motor/generator with one stator and one rotor unit. The roll-conductors and then each half the number of these, N, have direct contact with the outer respectively the inner radius of the cavity. Electrical energy is transferred to rotational energy via tangential forces. This is also true for the form with $Y < 90$ degrees which can be compared with Figure 2, where, however, the rolls shall have contact with the surrounding cylindrical surfaces. The rotor-rotation here will be equal to the double rotation of the roll-conductors in the same manner as in an usual rollbearing. The reluctance in the cavity is here decreased because there is only two bypassing-areas for the part-flux through one roll-conductor but is increased totally at the same time by the free-running distance, Δ , between the outer and inner parts of the system. In another alternative form with cog- or splines-formed roll-conductors the supporting rollers can disappear because the angle-division between individual rolls can be maintained by adapted gearpitch in the rolls and the cylindersurfaces.

Still another alternative with a stator-rotor construction is given in Figure 4 with the possibility to use conform and eventually equally big outer and inner roll-conductors with the specific ratio of radius. The rotation of the rolls and the rotor will be counterdirected with a forceful downgearing and thus suitable for motor/generators with low speed. Beyond the above described applications which

look like known electromagnetical systems the field will open, especially for forms with a homogeneous and closed outer magnet-system, for a number of unique applications. As some examples following may be mentioned:

1. energystoring, starting, rolling, braking with energystoring and backing wheels, externally controlled,
2. torque-activators on shafts, levers and similar,
3. gyrofree energystoring by adapted inertia of the counterrotating components,
4. energystoring buffert systems in power-lines,
5. pulsgenerators,
6. mechanically elastic equalizers at mechanical transmissions,
7. frequency converters etc.

CLAIMS

1. An electromagentic machine comprising a tubular space defined between inner and outer races, means for producing a radially directed magnetic field in the space, and an equal plurality of alternately arranged rolling elements and rollers disposed for free movement within the space, at least the rolling elements being electrically conductive.
2. An apparatus comprising a rotating electromagnetic system nearest replacing electrical motors, generators, converters and energyaccumulators mainly with radially directed magnetic field, defined by that across the magnetic field freely movable conductors (1 and 2) rotate in circular traces (7) and that from an even number of rolling conductors each other conductor is rolling off an outward limited and inward turned cylindrical surface or surfaces and the outer rolling off an inward limited and outward turned cylindrical surface or surfaces and that nearby conductors roll against each other.
3. An apparatus according to Claim 2, defined by that the unit (3) surrounding the cylindrical hollow, limited by the two against each other turned surfaces, is homogeneous and mainly made from magnetic material with devices for constant or variable magnetic fluxgeneration across the cylindersurfaces.
4. An apparatus according to Claims 2-3, defined by that the half number of or each half number of all roll-conductors are given two different rolling-off diameters (F and G) for rolling off partly against surrounding cylinder-surfaces partly mutually and that the diameter ratio is so chosen that no or eligible big sliding occurs.
5. An apparatus according to Claim 2-4, defined by that one of the cylindersurfaces surrounding the cylindrical hollow, of which one part of that surface is in contact with the series roll-conductors given two diameters and then one of those diameters (F), the other part is given such a diameter that it will not touch but is nearby that part of the roll-conductor which has been given the other diameter.
6. An apparatus according to Claim 2,4, and 5, defined by that the against each other turned cylindersurfaces are formed by an outer (5) and an

inner unit (6) which mutually can rotate .

7. An apparatus according to Claim 2, 4, 5, and 6, defined by that half of the even number of roll-conductors mutually are rolling off the in Claim 5 specified and mutually free rotating units (5 and 6), and that the other half number of the roll-conductors are rolling off someone of the surrounding cylinder-surfaces and nearby roll-conductors.

8. An apparatus according to Claim 2,4,5,6, and 10 7, defined by that each half of the even number of roll-conductors each of them are rolling off the nearby and in Claim 5 specified and mutually free rotating units (5 and 6).

9. An apparatus according to Claim 2-5, defined 15 by that coaxially a number of several cylindrical hollows (7, 8 e.t.c.) are filled with mutually with- or counter-rotating rollsystems.

10. An apparatus according to Claims 2-9, defined by that the roll-conductors or sections of them 20 mutually and also against surrounding cylinder surfaces are electrically isolated (11) and with electrical contact (10) are rolling off endplaced and in the other system fixed current collectors (14).

11. An apparatus according to Claim 2-10, defined 25 by that the current carrying roll-conductors or sections of them (12) are made from material with high magnetic conductivity.

12. An apparatus according to Claims 2-11, defined by that to diminish the friction-losses the 30 circular hollow/hollows completely or partly are evacuated.

13. An apparatus according to Claims 2-5, defined by that to get lowest possible gyroeffects in the total system the weight of the rolls and their inertia 35 with reference to their absolute directions of rotation are so formed that their contribution to the total sum of inertia completely or partly is cancelled.

14. Any of the electromagnetic machines substantially as herein described with reference to the 40 accompanying drawings.